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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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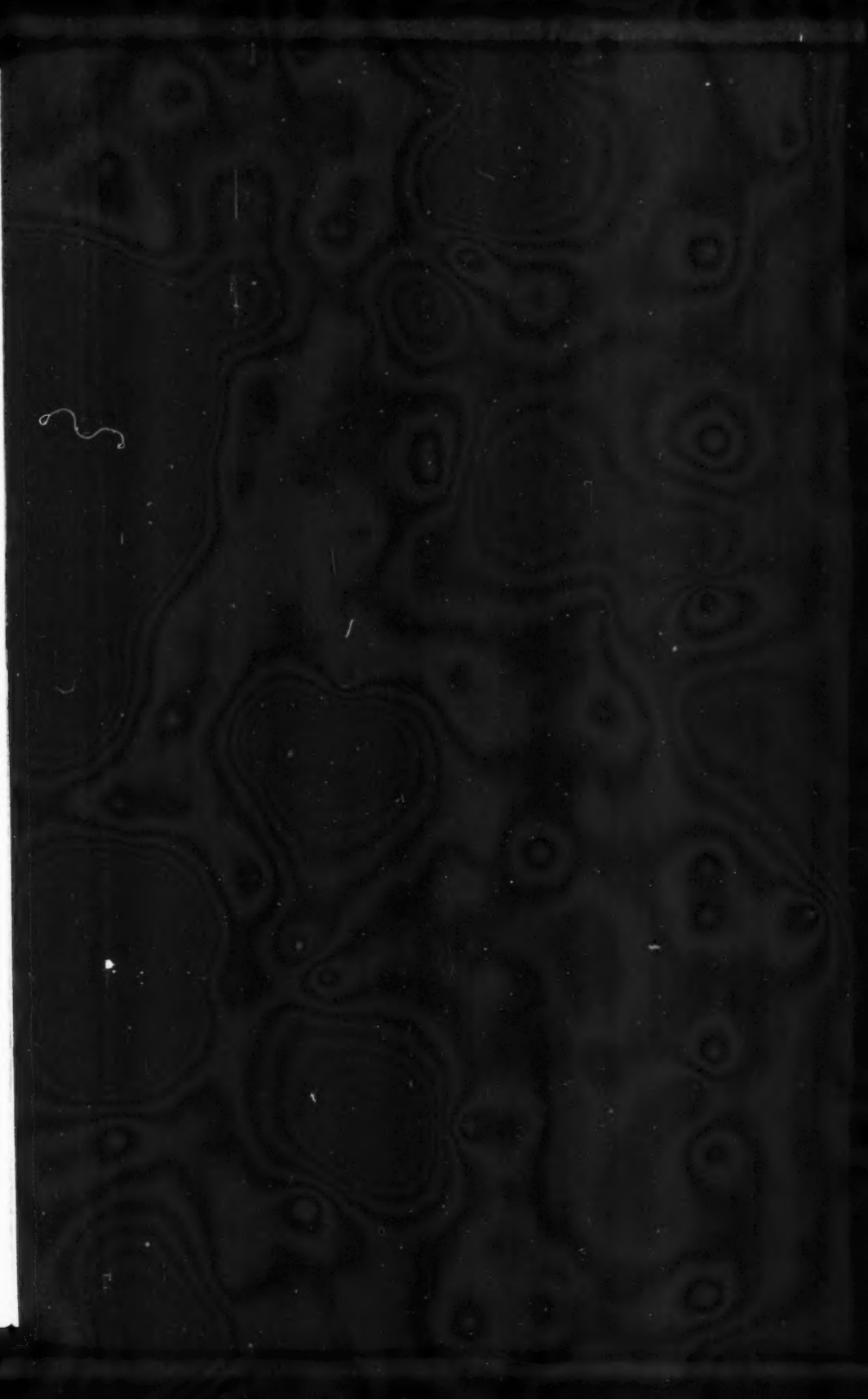

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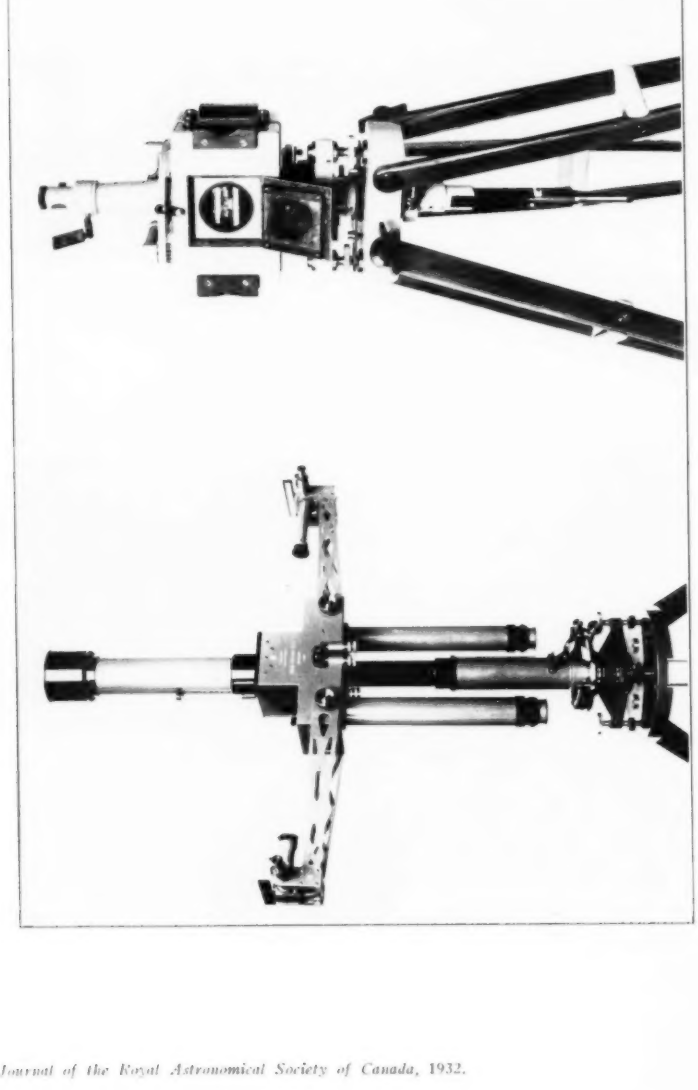
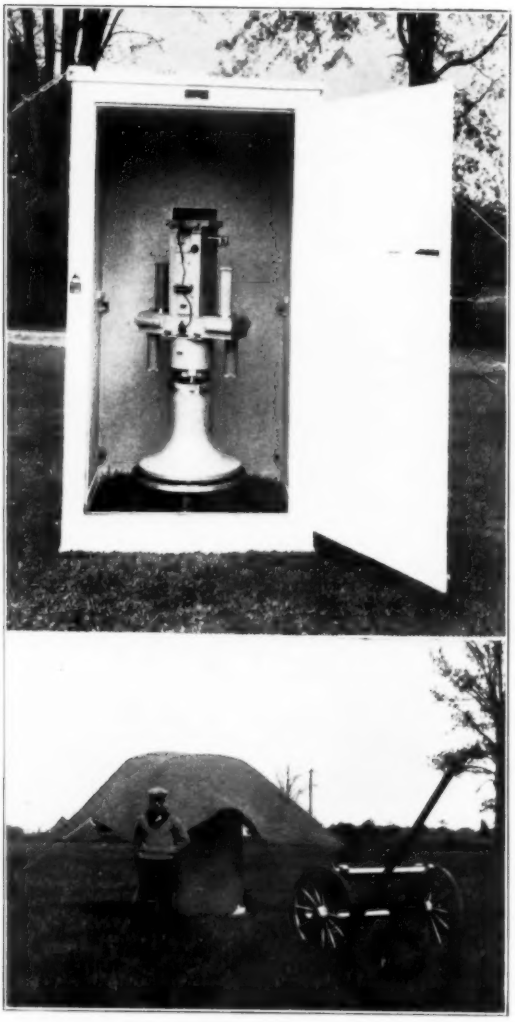


THE ASKANIA VERTICAL MAGNETOMETER

THE SÜSS TORSION BALANCE

PLATE II



Above. The Askania Torsion Balance in hut on Observatory grounds.
Below. The same set up for observation at station 41, Hazeldean fault.

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SURVEYS WITH THE TORSION BALANCE AND THE MAGNETOMETER IN EASTERN CANADA

By A. H. MILLER

(With Plates I, II)

INTRODUCTION

DURING the last several years investigations which have for their object the applicability of geophysical methods to the delineation of geological structure and to prospecting in Canada have been carried on by the Dominion Government. In addition to other investigations followed independently by the Geological Survey, gravitational and magnetic methods have for the last two years been the subject of joint study by the Dominion Observatory and the Geological Survey.

One Askania and one Süss torsion balance and four Askania magnetometers (two vertical and two horizontal) were purchased for the work and all have given quite satisfactory service.

Success with the torsion balance has for the most part been obtained indirectly by locating the geological structure that is favourable to the occurrence of the mineral deposit. In Canada one of these structures is that known as a "fault". For that and other reasons the investigations with the torsion balance were begun with the survey of faults. Surveys have been made of three faults in the vicinity of Ottawa where the geological conditions vary considerably. Owing to the effect produced by topography the torsion balance is best suited to investigation in flat or gently

undulating country. For the purpose of investigating the direct effect of an ore body and also of acquiring a knowledge of the type of terrain that renders the use of the torsion balance impracticable, a survey of a pyrite deposit in fairly rough terrain was made near Calabogie in Renfrew County, Ontario. Although the deposit is one which apparently is better adapted to investigation by the electrical method, still it was found possible to outline approximately by means of the gradient results the position of the ore body, and to estimate the angle at which it is dipping. In the case of shallow drift covering, the results of the survey emphasize the importance of correcting for the topography of the rock surface beneath the drift, and they also suggest the possibility that the instrument might be capable of giving more definite and useful information in the case of such a deposit in more even topography.

Surveys with the magnetometer have been made of the structures mentioned above and of some others, including ore deposits. Large magnetic anomalies were found in the vicinity of chromite deposits, but it is not determined yet—and it is doubtful—whether the method would be of use in locating chromite. It was found, however, that it could apparently be used to locate the boundary of the intrusive in which this mineral and also asbestos are found. In the case of two of the fault surveys results of value and capable of definite interpretation were obtained with the magnetometers. The presence of the pyrite deposit was indicated by the large magnetic anomalies that were encountered only in its vicinity, a circumstance that seems to be due not so much to the ore itself as to the country rock in the immediate vicinity of the ore.

There is given in what follows a discussion of some of the more interesting and representative results obtained from the surveys already described.

The Eötvös Torsion Balance and the Quantities it Measures

The instrument itself is essentially very simple, consisting of a light beam weighted at each end and supported by a delicate torsion wire. For the purpose of measuring the gradient it is necessary to have the weights at different levels and this, in the original and usual form, is accomplished by simply suspending one weight from

the end of the beam. When the beam is set in any azimuth, in so far as rotation about an axis along the length of the torsion wire is concerned, the system is kept in equilibrium by three couples: (1) that due to the torsion in the wire, (2) that resulting from the curvature of the level surface, (3) that produced by the gradient of gravity. By setting the beam in five* azimuths 72° apart and noting the deflection in each case from the mean position (which is also the position of no torsion in the wire) it is possible to determine from the constants of the instrument the gradient and the quantity called the H.D.T. (horizontal directing tendency) which is due to the differential curvature of the level surface and is in fact equal to gravity multiplied by the difference in curvature between the two principal planes (*i.e.* the planes in which the curvature is respectively greatest and least.)

In order to acquire a conception of the origin of the two gravitational couples without resorting to a mathematical analysis, let us suppose that the instrument is set up at some point in the northern hemisphere where we are concerned only with the normal effects produced by the earth as a whole and not with any effects that might be caused by local changes of density. Remembering that the effect on the instrument in so far as the curvature is concerned would be the same if the two weights were actually on the ends of the beam, it follows that the beam, if suspended by an entirely torsionless fibre and quite free to rotate, would rotate until the particles of the beam fell to their lowest level. This would be attained when the beam reached the direction east-west, because the curvature being least in this direction the particles composing the beam as a whole, and the end weights particularly, come closest in this position to the level or equipotential surface of the earth. The same argument applies in the case of the curvature when one of the weights is suspended, but it is not so simple to picture and is complicated by the effect produced by the gradient, as will presently be explained. Gravity increases as one goes north and consequently the gradient which measures the rate of change (in the direction of greatest change) is directed to the north. Referring to fig. 1, let us

*In order to reduce the time required for a determination the instrument is built with two parallel beams differing 180° in azimuth. In this case observations in only three azimuths are required.

suppose that the beam which is shown with the weights in the plane of the paper is in the east-west position. Since gravity increases as we go north, the level surfaces through the upper and the lower weights will be inclined to one another because the energy consumed in taking unit quantity of matter (equal gravity multiplied by the distance between the surfaces) from the lower to the upper level surface must remain the same irrespective of the distance from the plane of the paper. If we suppose the upper surface to be at right angles to the plane of the paper, then the lower level surface will be inclined upwards. Gravity, which at every point is at right angles to the level surface, will at the upper weight be entirely in the plane of the paper. At the lower weight it will have a component at right angles to the plane of the paper (*i.e.* to the north, and actually equal to the gradient of gravity multiplied by the vertical distance between the two weights), which tends to rotate the beam around into the north azimuth.

Fig. 1 — Diagram of Eötvös Balance.

The magnetometers are simply sensitive magnets mounted on knife edges and balanced by weights rigidly attached to the magnets so that they are capable of rapidly measuring very small changes in the earth's magnetic field.

Discussion of Results

Surveys with the Torsion Balance

Hull-Gloucester Fault at Leitrim. In fig. 3 the continuous line represents the components of the gradient resolved at right angles to the strike of the fault obtained from observations as indicated by the circles along the main traverse of the fault. The broken line represents the corresponding theoretical values of the gradient computed for the geological section indicated beneath the curve. The thicknesses of the different strata were supplied by Dr. M. E. Wilson of the Geological Survey. The density measurements were made partly from exposures in the vicinity and partly from samples supplied by Dr. Kindle of the Geological Survey. The density of the Precambrian is not known and was adjusted to best fit the

curves. Fig. 4 represents the corresponding effects for the H.D.T. or differential curvature. Positive ordinates represent components of the H.D.T. directed at right angles to the strike of the fault, while negative ordinates represent components parallel to the strike.

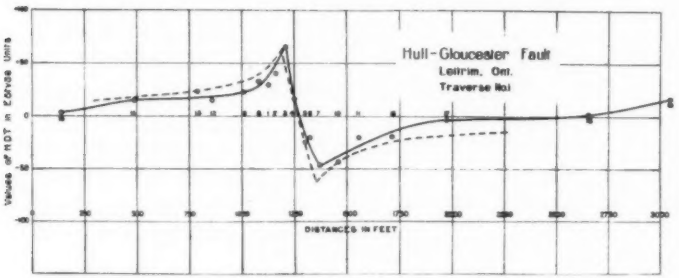

Fig. 3

In fig. 5 both the gradient and curvature effects for the above traverse are represented in plan. It is clear from this plan that the fault lies between stations 4 and 5 for the curvature changes by 90° between these two stations and it is here the maximum gradient is reached. The results of this traverse represent the gravitational effects produced by a fault very clearly (particularly the plan), better perhaps than is usual, probably because the fault in this case

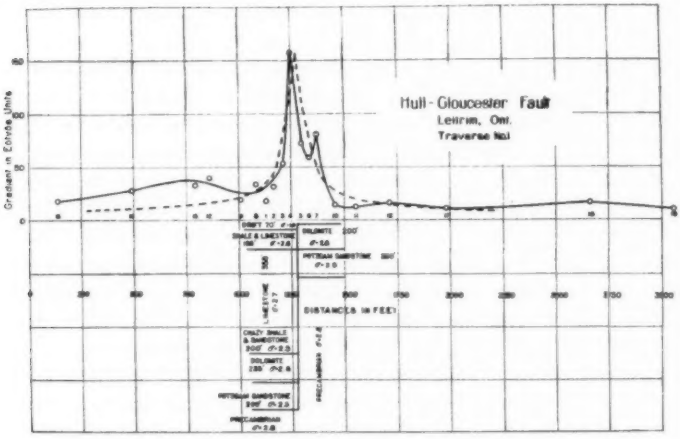

Fig. 4

is near the surface and also because it has a large throw. The shallowness of the fault is apparent from the curves which are characterized by sharp and large maxima. The depth of cover was arrived at from the theoretical formula connecting the distance between the maximum and minimum of the curvature on the one hand and the product of the depth of cover and the depth to the bottom of the block. Owing to the fact that the stratum of sandstone produces a gravitational effect opposite in sign to that of the dolomite, and also to the fact that the effects of the lower strata rapidly diminish in so far as the immediate vicinity of the strike is concerned, it follows that most of the effect near the fault is that due to the dolomite. In computing the amount of drift the depth that was used was there-

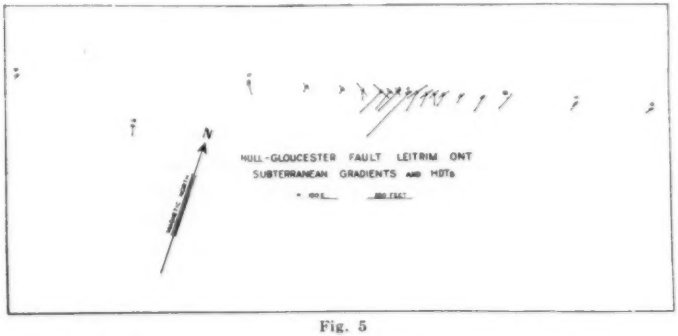

Fig. 5

fore taken as that to the bottom of the dolomite. The thickness of the drift in contact with the vertical surface of the dolomite was adjusted to best fit the two curves and was found to be 42 feet. The symmetry of the two curves about the central point may be taken as an indication that the fault is either vertical or very nearly so, at least in so far as the upper strata are concerned. The strike of the fault is indicated from the direction of the gradients and the curvature as shown in fig. 5, but actually it was obtained by joining the maximum gradients on two traverses. The strike of the fault so obtained agrees very well with that determined by Dr. Wilson from the outcrops.

If the fault were a simple one, involving only one difference in density, it would apparently be, in the case of this fault, a simple matter to estimate the thickness of sedimentary strata from this

density difference and the total change in gravity produced by the fault, which change may be computed from the gradient results. As a matter of interest it may be stated that, assuming a mean weighted density determined from the actual densities and the known thicknesses of the strata, the total thickness of the strata obtained from the computations agrees well with the known thickness. However, this result cannot be regarded of much importance except as a check on the assumed densities and thicknesses.

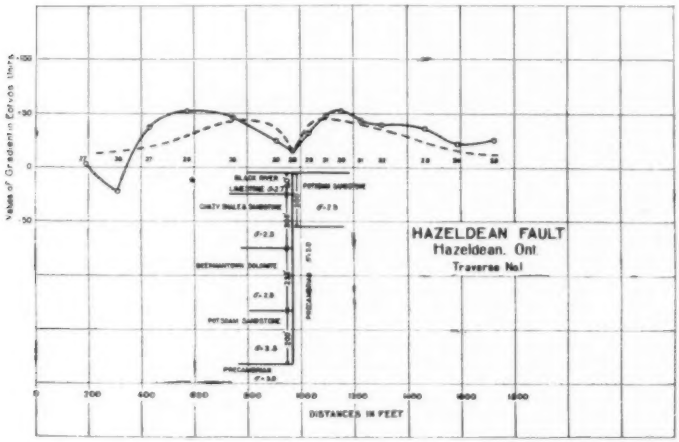

Fig. 6

It does appear, however, that in this case it was possible to determine with accuracy from the use of the instrument the position and strike of the fault. The results indicate a vertical fault and generally are in agreement with the known geological conditions.

Hazeldean Fault. The gradient graph (fig. 6) for the Hazeldean fault (survey of 1929) is interesting as it was from the minimum of the gradient that the fault was located. This is due to the large and local effect produced by the lighter sandstone in contact with the limestone, in conjunction with the opposite and more regional effect produced by the Precambrian in contact with the lower sedimentary strata. The results also indicate that, if the sandstone

were replaced by Precambrian and the fault covered with drift, it could be detected through a drift covering greater in depth than that represented by the sandstone (200 feet).

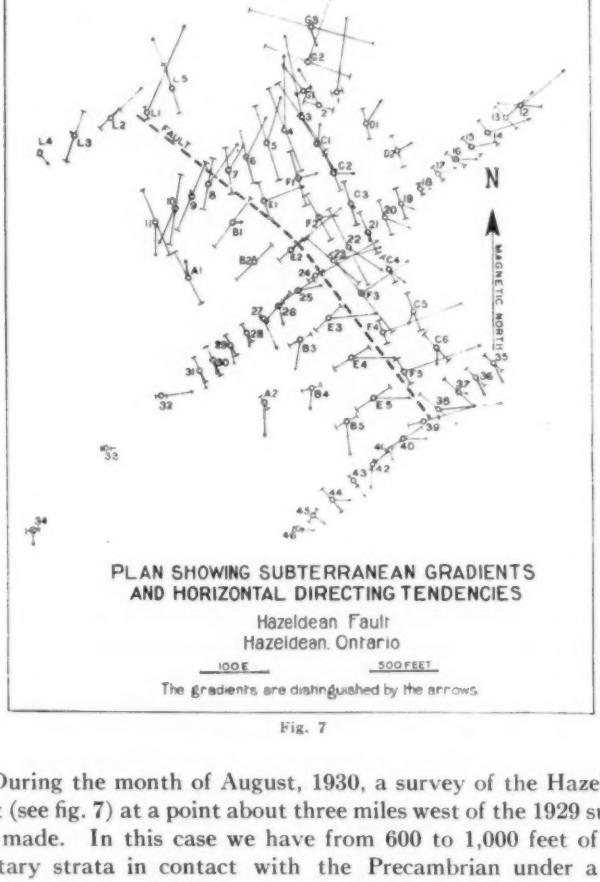

Fig. 7

During the month of August, 1930, a survey of the Hazeldean fault (see fig. 7) at a point about three miles west of the 1929 survey was made. In this case we have from 600 to 1,000 feet of sedimentary strata in contact with the Precambrian under a drift covering of about 60 feet or more. The area that was surveyed

over the Precambrian, or easterly, side of the fault forms a sort of drift-covered bay in the outcrops of Precambrian. Where the Precambrian is exposed its topography is more or less rough, and no doubt, as indicated from the results, it is of the same character

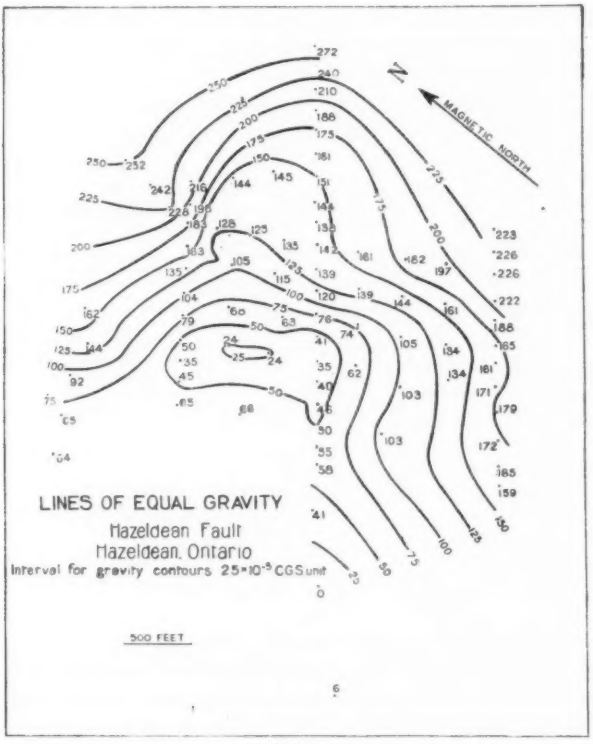

Fig. 8

beneath the drift. The large effects encountered in the area covered by the northwest section of the plan are either wholly within or very near these outcrops. While not yet fully corrected for topography, it seems probable that they are due in part to this proximity and to the irregularities in the Precambrian which in

this region are very near the surface. Disturbances apart from those produced by the fault are clearly shown in the effects over the sedimentary rocks. It would appear from them that along the fault we have a drift-filled basin, the tendency of which along the main traverse, owing to the curvature of the southern end of the basin, is to increase the curvature effects on the east side of the fault and to decrease them on the west. Some such cause as this is to be expected from a consideration of the plan of the results taken in conjunction with the gravity anomaly contours (see fig. 8).

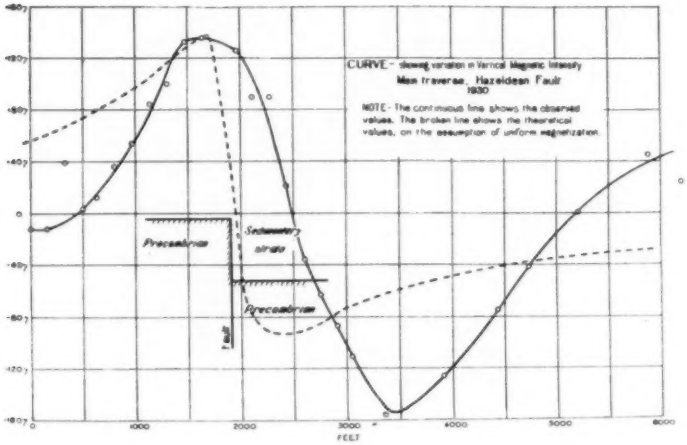

Fig. 10

The bottom of the basin is indicated by the 50 contour surrounding the gravity lows. A basin of about 60 feet in depth would be sufficient to account for the observed decrease in gravity. In conjunction with the gravitational results the magnetic results might be taken to indicate that it is possibly filled with drift which is more magnetic than the sedimentary rocks. (Along the main traverse the position of minimum intensity is apparently displaced to the westward. (See fig. 10). The effect of the basin could be shown more clearly if the isogams, or lines of equal gravity, were corrected for the effect produced by the fault. As a matter of fact

there are three distinct effects, each of which is evident in the influence it has on the lines of equal gravity: (1) the effect already mentioned, (2) that produced by the fault which would produce lines parallel to the strike of the fault and nearer to one another along the strike, (3) on the Precambrian side of the fault the rock outcrops along an arc which forms roughly a semicircle meeting the fault at points not far from the edges of the area covered by the survey. The region within the semicircle is drift-covered. The isogams within this drift-covered region of Precambrian, owing to the greater density of the rock, have a tendency also to become semicircular.

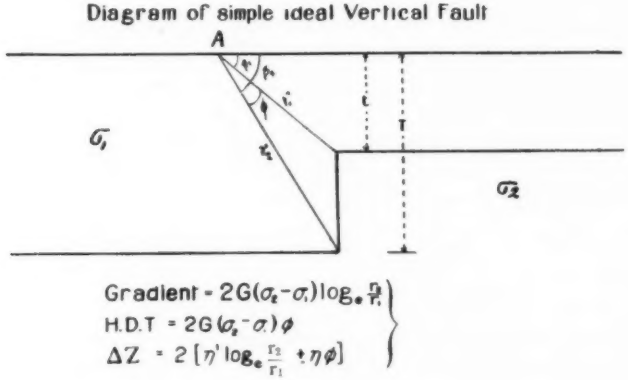

Fig. 2

In spite of these disturbances, or perhaps one might better say in addition to them, the strike of the fault is quite evident from the abrupt change in magnitude and direction of the curvature. Until some further computations are made to verify the above interpretation, it would perhaps be rather rash to draw any conclusions regarding the dip of the fault.

In the case of this survey, if any one of the quantities—mean density difference, depth of cover, and depth of sedimentary rocks —were assumed, it would be a simple matter to calculate the other quantities. (In the present case it is possible to do this as the depths are fairly well known). Theoretically it is possible to deter-

mine the quantities independently from the torsion balance results alone. In the present case it is at least possible to assign limits to these quantities from the results of the survey. If we start with the fact (see fig. 2) that ϕ cannot exceed a right angle (for a vertical fault) at the point where the H.D.T. is a maximum, take the average maximum H.D.T. effect produced by the fault to be about 65 Eötvös units, and use the formula for the curvature indicated in

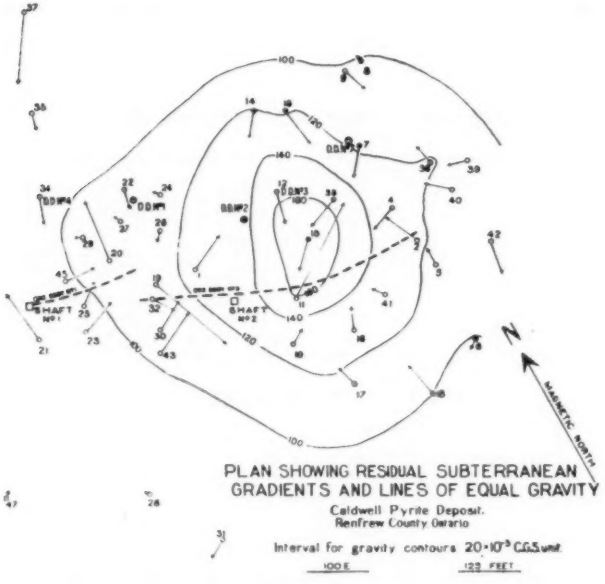

Fig. 11

fig. 2, it follows that $(\sigma_2 - \sigma_1)$ must be greater than 0.3. Using this value of the differential density in conjunction with the formula for the gradient where it has its maximum value (about 130 Eötvös units) and that connecting the depth of cover and the depth of sedimentary rocks on the one hand with the distance (equal to about 300 feet) of the maximum or minimum curvature from the fault ($\sqrt{tT}$ = distance), it follows that the depth of cover must be greater

than 59 feet and the thickness of the sedimentary strata less than 1,470 feet. This is no doubt a reasonable value for the drift cover but apparently an over-estimate for the thickness of the rock strata.

The Caldwell Pyrite Deposit. Most of the important facts in connection with this survey have been summarized in the introduction. Fig. 11 shows the lines of equal gravity and the gravity gradients. The gradients, in addition to being corrected for topography out to a distance of 400 metres, were also corrected for the effect produced by the contact of the rock surface underneath the drift. In most cases the covering was shallow and could be determined by sounding with a thin iron rod. In addition the gradients have been corrected for a general regional tendency which apparently persists over the whole area covered by the survey. It is apparent from the plan that the gradients outline roughly the position of No. 2 ore body and that the maximum value of gravity indicates the main mass of the ore to be in the vicinity of station 15 as it actually is. We have an indication of the dip to the north of the ore by the relatively large value of the gradient at station 11 compared with the magnitude of the gradients in the opposite direction on the north side.

Surveys with the Magnetometer

The Hazeldean Fault. The results of all the magnetic measurements that were taken in connection with the survey of this fault are shown in fig. 9. The strike of the fault is indicated approximately by the line of maximum positive anomaly. The Precambrian rocks are evidently, as one would expect, more magnetic than the sedimentary strata. The curve showing the observed results across the main traverse (see fig. 10) is of the form to be expected if the Precambrian were uniformly magnetized. However, the agreement between observed and theoretical values does not go much beyond this. The two curves were made to fit at the maximum, the maximum value from the formula (see fig. 2) being equated to the observed value. This equation gives for the susceptibility the value 988×10^{-6} c.g.s. unit which may represent an average value of the susceptibility of the Precambrian. On the assumption of uniform magnetization that has been made, the

observed curve (distance between maximum and minimum 1,500 feet) would indicate a throw of 3,000 feet, which is at least three times too great.

In the formulae representing the gravitational and magnetic

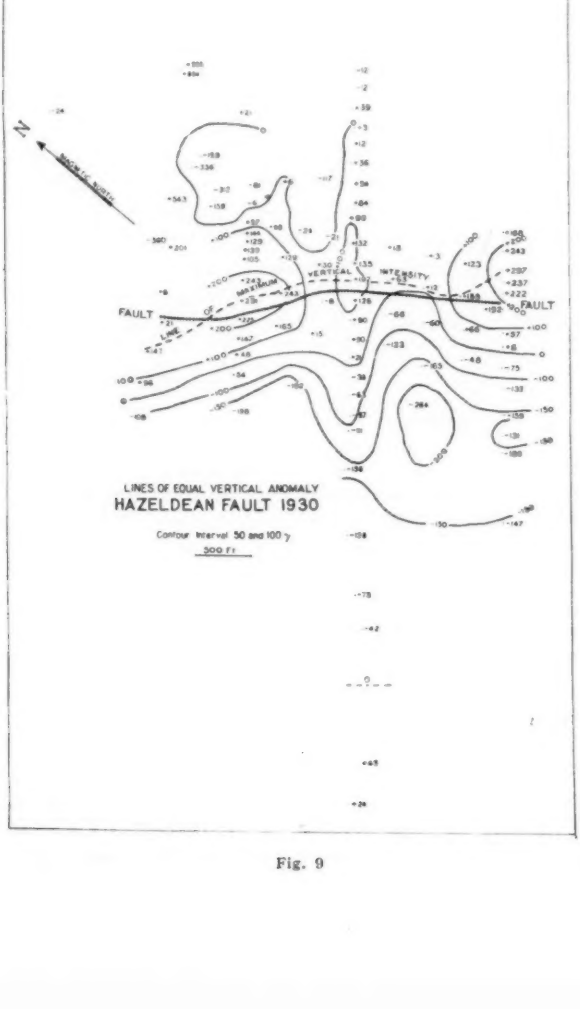

Fig. 9

effects produced by a simple ideal vertical fault, at the bottom of fig. 2, G represents the gravitational constant $=66.7 \times 10^{-9}$ c.g.s. unit, $\sigma_2 - \sigma_1$ the difference in density between the strata, ΔZ the anomaly in the magnetic vertical intensity (on the assumption of uniform magnetization), η' the density of magnetic charge on the

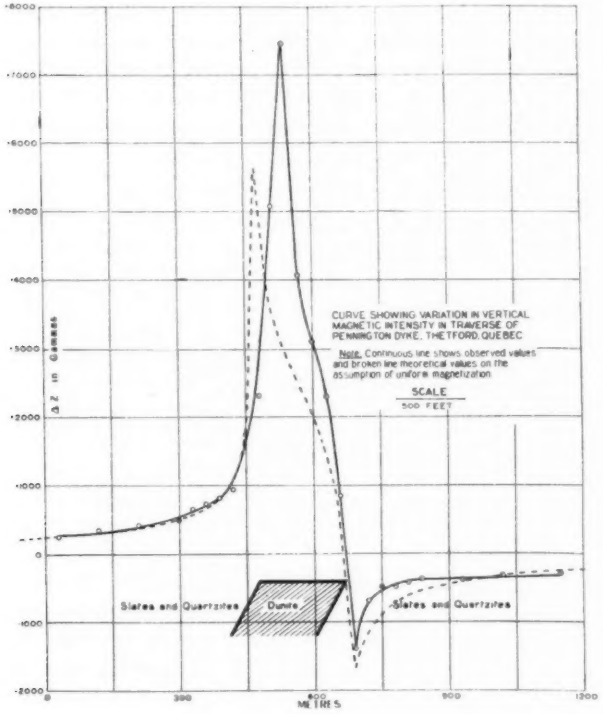
CURVE SHOWING VARIATION IN VERTICAL MAGNETIC INTENSITY IN TRAVERSE OF PENNINGTON DYKE, THETFORD, QUEBEC
Note. Continuous line shows observed values and broken line theoretical values on the assumption of uniform magnetization
SCALE
500 FEET
ΔZ in Gauss
Slates and Quartzites
Dunite
Slates and Quartzites
METRES

Fig. 12

fault plane, and η the density on the surface of the Precambrian. The surface density, η, is equal to K (the susceptibility of the Pre cambrian) multiplied by Z, the vertical intensity of the earth's field, while η' is equal to K multiplied by the component of the earth's field at right angles to the fault plane.

Dunite Intrusive at Thetford, Quebec. The surveys of the chromite deposits established the fact that large anomalies (both positive and negative) exist in the vicinity of these deposits. These may or may not persist (but probably do) throughout the dunite area. Specimens of the country rock selected from one of the deposits were in certain cases far more magnetic and in most cases actually did exhibit more effect than any of a dozen ore samples selected from the deposit. Notwithstanding this distinction, the location of these deposits by the magnetometer would seem to be a matter of some difficulty as the magnetic properties of the surrounding rocks, judging from the few specimens collected, appear to be so variable.

Fig. 12 represents the traverse of Pennington dyke, which is an offshoot of the main dunite intrusive. The rocks in the dyke and the slates and quartzites dip to the south at an angle of about 60° and extend to great depths. At the location of the survey the dyke was trenched and is as a rule not more than six feet beneath the surface. The actual boundaries are indicated by the section in the figure. It will be seen that they correspond approximately with the maximum and minimum in ΔZ. Over the slates and quartzites the magnetic field is apparently very uniform. It was measured at several places (not shown in the figure) in the quartzites, and even farther than a mile from the dyke was found to vary little.

In fig. 12 the numerical values for the theoretical curve were obtained by equating the theoretical effect to the observed at three points, one midway between the maximum and minimum and two other points equidistant on either side of the dyke. The mean obtained from these three equations gave for the susceptibility of the rock forming the dyke the value approximately of $10{,}000 \times 10^{-6}$. The agreement between the two curves is fairly good. The observed maximum is apparently shifted to the right, probably due to the fact that the more basic rocks are to be found on the south side of the dyke (*i.e.* to the right in the figure). Owing to the fact that the dyke is so close to the surface it is of interest to note that the effects beyond the two edges (*i.e.* in the figure to left and right of the upper surface of the dyke) are due almost entirely to the magnetism on the sides of the dyke.

RADIO TALKS OVER CFCF (VICTORIA, B.C.)

By W. E. Harper

XLVI—The Form and Dimensions of "The Starry Universe"

(*May* 5, 1931)

WE have come to realize that the sun, which dominates the sky so far as dwellers on earth are concerned, is a star pure and simple like the host of other luminous orbs seen on a clear night. Its attendant planets, Venus, Mars and the rest of the family, can easily be distinguished from the stars and are found to be relatively close to the sun in comparison with the immense distances of the stars. We can thus look upon the sun and its family simply as one of the stars. In my last talk I had occasion to refer to the density of the stars throughout space. I compared them to specks of dust, the stars enjoying an isolation comparable to that of a single dust particle in the largest building in our respective cities. Another striking illustration, due to Eddington, is that they are no more crowded in space than would twenty tennis balls be roaming through the whole interior of the earth, if it were a hollow shell.

My present aim is to state the distances to which the stars extend in all directions; in other words to outline the form and extent of the universe. The naked eye can see about 5,000 stars, though only one half of that number at any one time. A one-inch telescope reveals 100,000 whilst the largest telescopes will reveal about a thousand million stars. Each increase in telescopic power adds to the number and we can scarcely set a limit, it would seem, to the number that must exist.

The stars have been divided into grades of brightness, each grade, or magnitude as it is termed, being 2.5 times as bright as the next succeeding one. Now if the stars were actually all of the same intrinsic brightness and uniformly distributed through space, the geometry of the problem would tell us there would be almost four times as many stars of any magnitude as there are of those one magnitude brighter. This comes from the greater space occupied by the stars which are rendered faint by reason of distance.

But this ratio, instead of being four times, starts off at about

three, for the brightest stars we see, and gradually lessens until when we come to the limit reached by the big telescopes the ratio is only 1.8 and is rapidly decreasing. It would seem that we were approaching a limit where the stars were rapidly thinning out, so much so that larger telescopes, when we secure them, will not reveal many additional stars.

By trying to estimate just how this ratio diminishes beyond the point where we can actually measure it, attempts have been made to deduce the total number of stars in the universe. It is a risky proceeding at best and no wonder that estimates vary all the way from 3,000 to 30,000 millions.

In one direction the stars extend to much greater distances than in a direction at right angles thereto. The great band of light circling the sky and popularly known as the Milky Way represents the plane in which the stellar universe has its greatest diameter. We look through a greater depth of stars when looking towards the Milky Way than when looking at regions of the sky 90° distant. Thus in form the stellar universe may be likened to a disk or thin watch, the long diameter being probably from five to ten times its shorter one. Our largest telescopes can penetrate to the limit of the shorter diameter but not to that represented by the longer one.

We sometimes use as unit of measurement of stellar distances the distance that light travels in one year at a velocity of approximately 186,000 miles per second. This unit is thus called a "light-year" and is approximately six million, million miles. The long diameter of our universe has been considered to be of the order of 300,000 light years and the shorter one about one-fifth or one-tenth of that amount. These values were based upon what is known as the "luminosity law" derived by Shapley and are dependent upon a none-too-secure foundation. While some astronomers have felt that the correct values are only about one-third of those given —and Eddington, one of the outstanding astronomers, uses the value of 100,000 light years for the diameter—recent work seems to indicate a mean between these two limits or a long diameter to our stellar universe of roughly 200,000 light years. The shorter diameter would then be of the order of 30,000 light years.

In this flattened form of space are scattered these millions of stars, but they are not uniformly distributed. The naked eye itself can detect the irregular way they are scattered, quite apart from the increased numbers as we approach the plane of the Milky Way. I think we all know something about the irregular way grass seed falls on the lawn when one is attempting to sow it by hand. It seems to fall in bunches. In much the same way it would seem the stars were strewn, sparse in some places and thickly congregated in other places. Our whole flattened stellar universe seems to consist, then, of star groups, clusters and single stars in greater or less density from place to place. Moreover, the bulk of the stars ordinarily visible in moderate telescopes seem to partake somewhat of a "local cluster" whose diameter is only a few per cent of that mentioned just now for the whole system.

One more fact must be added to those already given to give you a proper conception of our stellar universe. It is slowly rotating about an axis parallel to the shorter diameter. The suggestion came first from the similarity between our own starry universe and those distant spiral nebulæ which are now recognized as other island universes of stars, and which are known to be in rotation.

Summing up, then, we have from three to thirty thousand million stars, each comparable to our sun, congregated in space, the form of which is like a thin watch whose longer diameter is of the order of 200,000 light years and shorter 30,000 light years. The whole system is in rotation about an axis parallel to the shorter diameter. Such is our galactic universe.

XLVII—LIGHT WAVES

(*May* 19, 1931)

IF we throw a stone into a still pond of water we will note the circular waves which are produced going farther and farther from the centre of the disturbance until they are lost in the distance or break upon the shore. The size of the waves will give infor-

mation concerning the size of the object thrown. Similarly, on larger bodies of water we can readily distinguish between those produced by a giant liner or a small canoe, to say nothing of the very small oscillations set up by the fluttering of a drowning insect.

In a somewhat similar manner, the sound waves which reach the ear give information regarding the source of the sound. We can tell in general the direction of the source, its intensity or loudness, its pitch and character. And since light gives precisely the same kind of information it is only natural to infer that light is also a wave motion of some sort. Without serious inaccuracy we can so regard it.

Ordinary sound waves are the result of some disturbance in a medium—air for example—which alternately causes the particles to be compressed and rarefied. The distance between points of maximum compression is called the wave length. Thus a tuning fork beating 250 times per second will send out waves a little over four feet long since sound travels about 1,100 feet per second. A tuning fork beating faster will give shorter wave lengths with a consequent higher pitch to the note.

In the case of light, the waves are extremely short. The average wave-length for visible light is about 1/50,000 of an inch, the longer waves of red light being about 1/35,000 of an inch and the shorter violet ones about 1/70,000 of an inch. Of course, the extreme limits at either end of the scale to which the retina of the human eye is sensitive are somewhat dependent upon the person concerned.

But the radiations that reach us in the form of light are not the only ones that come to us from a glowing object. If we stand before an open grate we see the fire burning by "visual" light, but we also recognize its presence by the waves of heat radiated to us from the source. The wave-lengths of these radiations are much longer than those of visual light. Similarly, at the other end of the scale beyond the violet are radiations of extremely short wave-length.

Let me summarize very briefly the various kinds of radiation with which we have acquaintance, mentioning the approximate lengths of the waves concerned. Radio waves that carry my voice

out to you are among the longest known. They range from waves as short as four inches to those of ten or more miles in length. This particular station broadcasts on a wave-length of 479 metres, which means waves about three tenths of a mile in length are carrying the speaker's words to you. Just shorter than radio waves are the so-called short electric waves from the lower limit of the radio waves, four inches, to waves 1/100 of an inch. Then come the heat waves from this lower limit to the upper limit of visible light which is about 1/30,000 of an inch. The range of visible light is very small, extending from this limit to about 1/70,000 of an inch. Ultra-violet radiation which affects specially sensitized photographic plates carries us down the scale to waves one-thirtieth this length and below these in turn we have X-rays, 1/400 of violet light, whilst recent years have brought us knowledge of waves even shorter in the penetrating cosmic radiation from outer space.

These are the main types of electromagnetic radiation which are believed to possess in empty space essentially the same qualities. All travel across empty space at the same rate of speed which is that of the velocity of light, namely, 186,000 miles per second.

For the most part, it is visible light that astronomers are concerned with, and in particular that portion of it in the blue-violet to which the ordinary photographic plate is most sensitive. By means of an analysing device called a spectroscope, which spreads the light from a source out in a coloured band—the so-called spectrum —we learn much of the source. In this spectrum the colours, or wave-lengths, are arranged side by side and we can note if the source is rich or deficient in any particular colour. And just as we are aware from experience that a white-hot poker is hotter than one which glows only a dull red so we can learn from the spectrum something of the temperature of the light source, be it the sun or some other star. The reddish stars are the cooler ones, the bluish-white ones the hottest.

In the spectrum too are certain markings or lines whose presence indicates the presence in the star of different metals. From our laboratory experience we know the characteristic set of lines peculiar to each of the elements; and when we recognize these lines in the analysed light of the star we can say with assurance that such

metals are also present in the star itself. That is to say, we can tell the composition of the star by an analysis of the light waves that reach us.

Moreover, while there is no doubt as to the identification of these lines, their character varies somewhat from star to star. Some of them may be unduly intense in one star or correspondingly weak in another. It is learned in various other ways that the stars are not all of one size; some are giant, massive bodies; others are dwarfs. A relationship has now been established between the intensities of these sensitive lines and the actual mass or luminosity of the star concerned, so that by taking note of their intensities we can know with assurance of the real size and luminosity of the light-giving star.

Moreover, if all lines are sharp and narrow we know by comparison with our laboratory experience that they originate in stellar atmospheres of very low density and *vice versa* if they are broad and fuzzy they originate in stars of high density.

But possibly greatest of all the knowledge they bring to us is the speed with which the light-giving star is moving either toward us or away from us. This phase of the question would require too much time to explain here but to sum up, we have learned that these messengers of light from a star when analysed and deciphered make us acquainted with practically everything about the star, its mass, size, density, real brightness, the metals of which it is composed and its motion in space. Truly the message they bear is all comprehensive.

XLVIII—WHAT TIME IS IT?

(*June* 16, 1931)

THE question that serves for our topic this evening is one which is asked as often as any other that we could think of. The various telephone and telegraph companies which at first allowed their employees to give the correct time to all enquirers, had to cease doing so because their lines were so choked with such calls that legitimate business was seriously interfered with.

A great development has taken place in methods of measuring time from those used in primeval days. The burning of a rope with knots regularly spaced along its length, the draining of sand or water from one vessel into another and the various types of sun dials were all attempts at improving the method of measuring the flight of time.

Modern determinations of time are all based upon the uniform rotation of the earth upon its axis. The interval of time required to make a complete rotation is called a day and it is conveniently divided into 24 hours of 60 minutes each. Thus the earth is our master clock and if we had suitable points marked out in space, we could tell the time by noting when our position on the earth turned past these points. The stars are the nearest approach to fixed points in space and it is observations of their positions from time to time that enable us to keep our mechanical clocks accurate to within a hundredth of a second.

It might be thought that since our lives are regulated more by the sun than by the stars that the sun should be the body to be observed. Unfortunately the sun's motion is erratic; the interval of time between successive passages across our meridian, or "transits" so-called, varies by appreciable amounts; and if astronomers adopted the actual sun as the standard to go by, the days would be of unequal length. A compromise is effected by introducing a fictitious sun which moves uniformly, sometimes ahead of the real sun, sometimes behind it, but whose rate is the average value for the true sun. Since observations cannot be made upon an imaginary body, the procedure adopted is to observe well determined stars and mathematically deduce the position of the fictitious, or mean sun.

To observe these stars for time, a small telescope is used which is free to swing in a north and south line—known as our meridian. It is pointed towards one of these time-stars as it is about to cross our meridian and the instant it crosses the central wire is recorded. In practice several short intervals on either side of the exact centre are noted and not one but many stars are used before a value of the clock correction is considered as determined.

In the observatory at the national capital, Ottawa, are kept the

master clocks which give us our time. Formerly only one was used; now three, I think, have been secured so as to check more thoroughly one another and provide for emergencies. They are placed in a room in the basement, kept so far as possible at constant temperatrue and pressure and away from disturbances of any kind. By these observations on the stars a check is kept on their errors and thus we have accurate mean time.

Local mean noon, that is the instant when the mean sun is on the meridian, will occur at different times for places differing in longitude. In order to avoid confusion standard time zones were established in 1883. All the points in each zone use one uniform time. These zones are on even hours and are measured from Greenwich, which is considered the zero meridian. In Canada we have six time zones called respectively Atlantic, Eastern, Central, Mountain, Pacific and Yukon and in travelling from the extreme east to the extreme western limits of our land, it is necessary to turn our watches back one hour on five different occasions. Canada led in the movement for these time zones and standard time has now been adopted practically the world over.

The distribution of time calls for only brief explanation. By coupling the master clock at Ottawa to the telegraph lines at a stated hour each day, the individual seconds are thus recorded in all telegraph offices throughout the land. Accurate time is thus available to train despatchers and conductors so that there need be no accident through faulty time pieces. More recently wireless signals are sent out from various places throughout the civilized world and these are taken advantage of, not only by those who desire accurate time for general use but by those as well who are engaged in special researches requiring time accurate to the hundredth of a second or even less. Such stations are maintained by nearly all European countries, the signals from the Eiffel Tower in France being those best known. Canadians are more familiar with those sent out from the navy yard at Arlington, Md., which are broadcast at noon, 10 o'clock in the evening and 3 o'clock in the morning, Eastern Standard Time.

These have been put to many practical uses. Surveyors marking international boundaries can, and do, make use of them to determine

where the boundary line shall lie. Others studying the form of the earth by means of gravity determinations avail themselves of these signals to check their seconds pendulums, and as a by-product local idiosyncrasies of the pendulum can be traced to oil deposits below the surface of the earth.

In Paris it is possible now to get accurate time by simply getting telephone connection with the master clock itself. An automatic device will simply answer something like this "It is now nineteen hours and twenty-two minutes," signifying 7.22 p.m. as they use the 24-hour system in France. Seconds are not used as yet but such could easily be provided for. Such devices have not yet made their appearance with us but with all the manufacturers of time pieces wishing to give us the correct time over the radio, there would seem to be no need of such.

THE EXPANSION OF THE UNIVERSE*

By A. S. E.

WE may, if we like, regard the "expansion of the universe" as an observational phenomenon independent of theories of curved space. This is a deviation from the historical order; for when in 1917 W. de Sitter put forward his famous theory, predicting large and predominantly receding velocities of distant objects, he could quote only 3 measured velocities of spiral nebulæ in support. By 1922 V. M. Slipher had furnished 40 radial velocities of spirals, of which only 5 were negative. Interesting additions have since been made at Mt. Wilson, including some very large receding velocities of faint and presumably distant nebulæ. The few negative velocities have disappeared, or been reduced to insignificance, by the recognition of our own orbital motion round the centre of the galactic system. It appears, then, that the spiral nebulæ are running away from us with remarkable unanimity; the speed of recession increases with increasing distance, the amount being roughly 500 km. per sec. per megaparsec distance. At this rate they will double their distances from us every 1,400 million years, and scatter apart from one another as much as they scatter away from us. Whether or not this represents an "expansion of space", it is an expansion of the material universe alarmingly rapid to those who were becoming accustomed to thinking in billions of years.

The theoretical explanation of this effect is due to de Sitter, but the actual hypothesis or law involved in it is due to Einstein. In order to meet certain philosophical difficulties connected with absolute rotation, Einstein in 1917 amended his law of gravitation by the addition of a minute "cosmical term," so as to read $G_{\mu\nu} = \lambda g_{\mu\nu}$ instead of $G_{\mu\nu} = 0$. It can be shown that this adds to the ordinary gravitational attraction of bodies a repulsion from the origin varying directly as the distance. In general this repulsion will gain the upper hand at sufficiently great distances; that essentially is de Sitter's explanation of why these remote astronomical

*This discussion by Professor Eddington is printed in *Monthly Notices*, February, 1931.—Editor.

objects are being scattered away from us (and from each other). Einstein's original reason for introducing $\lambda g_{\mu\nu}$ would probably not be pressed today. But the term plays a fundamental part in Weyl's and subsequent developments of Einstein's theory. It has been shown by me that the term is necessary if the principle of relativity is pushed to its logical conclusion, so that size (or scale of magnitude) is relative and not absolute. The law $G_{\mu\nu} = \lambda g_{\mu\nu}$ is a simple expression of the fact that our survey of the world is made by instruments which are themselves part of the world; so that extensions are not measured absolutely but relatively to extensions implicit in the structure (and especially the curvature) of space-time. In short, when the law of gravitation is taken to be of this form, a rational explanation of it can be given.

Thus far the finitude of space has not been mentioned; but the conception of a repulsive force, increasing indefinitely as the distance increases, acutely raises the question, What is to be done about infinity? Within a sphere of uniform density the gravitational attraction is proportional to the distance from the centre; it is therefore proportional to the repulsion, which likewise varies as the distance. Thus there is a particular density of uniform distribution for which the attraction and repulsion will balance throughout. It is well known that density involves curvature of space, and in this case, if the uniform distribution extends far enough, space closes up, forming a sphere of definite radius. The distribution of matter of uniform density, filling a closed space, and in equilibrium owing to the balancing of gravitational attraction and cosmical repulsion, is known as an "Einstein world." Both the radius and the density must have a particular value fixed by the constant λ; but, of course, these values remain unknown until we have some observational means of determining λ. In contrast we can set a "de Sitter world," which is entirely empty, so that the cosmical repulsion acts without opposition. Neither world could be seriously suggested as an exact representation of the universe; but the former will be the appropriate first approximation if the masses of the spiral nebulæ are on the average sufficient to restrain by their mutual gravitation the scattering tendency, and

the latter will be the appropriate model if gravitation between the galaxies is small compared with the scattering term. Since we observe a recession of the galaxies the latter approximation has been preferred.

There was an obvious inconvenience in working with only two model universes, one of which admitted matter but no motion and the other motion but no matter; and efforts were made to find intermediate solutions. This was made rather more difficult by the fact that de Sitter employed a transformation of time-reckoning which obscured the connection of his world with Einstein's. Nevertheless solutions were found, published, and forgotten, buried like a needle in the haystack of relativity literature. Such a solution was given by A. Friedman in 1922. In 1927 Abbé G. Lemaître not only rediscovered the series of solutions intermediate between Einstein's and de Sitter's, but worked out the astronomical consequences in a complete manner, obtaining results of remarkable interest. This paper also remained unknown. Wider publicity was obtained by H. P. Robertson, who again found the solutions in 1929; but his point of view was mathematical and logical rather than astronomical.

Lemaître's paper came to light again in 1930 in connection with an informal communication given at a meeting of the Royal Astronomical Society by de Sitter. Making (as I think) a rather excessive estimate of the masses of the nebulæ, de Sitter propounded the dilemma that the actual universe apparently contained enough matter to make it an Einstein world and enough motion to make it a de Sitter world. This naturally called attention to the need of intermediate solutions for handling such a question. Some of my remarks in the discussion were reported, and Lemaître (who had once been a student of mine) wrote to me on the subject, drawing attention to his paper. I was at that time working with G. C. McVittie on the question whether Einstein's world is stable, using Robertson's paper as a basis. The elegance and completeness of Lemaître's work was recognized by de Sitter and myself, and it has been the subject of papers by both of us. I pointed out that it was immediately deducible from his formulæ that Einstein's

world is unstable, so that an expanding or a contracting universe is an inevitable result of Einstein's law of gravitation. The question remains whether it could have been predicted that expansion rather than contraction will actually occur. I showed that conversion of matter into radiation tends to retard the expansion and therefore cannot be the cause. The effect of the gradual condensation of the matter into galaxies has been examined by G. C. McVittie and W. H. McCrea. Their first conclusion was that this also would tend to cause contraction; but recently McVittie, in a far-reaching investigation has obtained the opposite result, so that it seems likely that this is what originally started the expansion. The question, however, is one of extreme difficulty, and McVittie's result may not be definitive. It should be understood that the discussion concerns only the initial cause which decided between expansion and contraction. Once started, the expansion or contraction continues at an accelerated rate in accordance with Einstein's law of gravitation, and without any other maintaining causes.

"Lemaître's world" is also a model in that it represents the universe as a uniform spherical distribution of matter; there is no reason why the actual shape should not be highly irregular. But it serves to exhibit the evolution of a universe, starting presumably as an Einstein world in equilibrium but unstable, and progressing towards de Sitter's world as the ultimate limit when the expansion has reduced the density so much that it may be treated as empty so far as gravitation is concerned. To picture it we may imagine the nebulæ to be inbedded in the surface of a rubber balloon which is being inflated, so that objects "at rest" are actually becoming more and more widely separated. An interesting point is that the random motions of the galaxies will decrease as the expansion increases, so that if the expansion of the universe is already large, the motions of the spiral nebulæ should correspond to the cosmical repulsion without much masking by other effects. The expansion of space affects only the separation of the galaxies; it does not cause the galaxies themselves to become any larger. (De Sitter disagrees with me on this point). The following numerical results

rest on the provisional assumption that the observed recession of 500 km. per sec. per megaparsec corresponds to the cosmical repulsion undiminished by any important gravitational attraction between the nebulæ. The initial radius of space was 1,200 million light-years and the whole mass of the universe is 10^{22} times the sun. The present radius is practically incalculable, but is supposed to be considerably larger. The radius increases with the time in geometrical progression, and ultimately objects must separate at a rate greater than the velocity of light; there is no contradiction in this, for the separation corresponds not to dynamical motion but to inflation of space. Objects separating faster than the velocity of light are cut off from any causal influence on one another, so that in time the universe will become virtually a number of disconnected universes no longer bearing any physical relation to one another. It was one of the advantages of de Sitter's original representation that it exhibited this gradual disappearance of parts of the universe "below our horizon" more prominently than Lemaitre's representation does. Probably a great part of the universe is already below our horizon. We might still see it owing to the lag of light-time—that is to say, we should see the events which happened in it before it passed below the horizon, but light from the events "now" happening will never reach us.

We can, if we prefer, say that the universe is of constant size, and that we ourselves are becoming smaller and smaller. All our surroundings, our metre scales, our atomic standards, even the stars and nebulæ, but not intergalactic distances, share in this diminution of scale. If we do not tamper with fundamental constants, such as the velocity of light, our time-scale will also diminish in the same progression. We shall actually vanish. Successive years in terrestrial reckoning are periods diminishing in geometrical progression according to the cosmical time-reckoning, so that an infinite number of years adds up to a finite cosmical time. The lapse of that time puts an end to matter—and to the difficulties to which the occurrence of matter gives rise. But this is at the cost of supposing that "true time" is a function of the cosmos rather than of human consciousness.

Finally, I repeat my personal conviction that the cosmical constant λ is connected with the ratio between electromagnetic and gravitational units, and sooner or later a theory giving an accurate value of λ will be forthcoming. We shall then have a purely theoretical prediction of the speed of recession of the spiral nebulæ (if undisturbed by mutual gravitation) to compare wth astronomical observation.

REVIEW OF PUBLICATIONS

Signals from the Stars, by George Ellery Hale. 138 p., 5×7¾ in. N.Y.: Scribners, 1931. Price $2.00.

This is another small book from the pen of Dr. Hale dealing with the work of the Mount Wilson Observatory. Its four chapters are entitled: The Possibilities of Large Telescopes; Exploring the Solar Atmosphere; Signals from the Stars; Building the 200-inch Telescope. Everyone will agree that Mount Wilson is our greatest centre of astronomical research, and Dr. Hale, being in the midst of it, is able to give those personal details which make a narrative specially interesting. The book is full of such. In the sketch of solar investigation are many incidents in his own observational work. The last chapter outlines some of the extraordinary problems encountered in designing the 200-inch, some of which are still far from solution; also, there is an account of the work of Hubble and Humason on the enormous speed and the related distance of the faint nebulae.

The book is written in excellent style and it contains numerous remarkable pictures well reproduced.

C. A. C.

Astronomische Paradoxa, von Georg Alter. 72 p., 6×9½ in. Prague, Calve'schen Universitäts Buchhandlung, 1932. Price 25 crowns.

As the author states in the preface, the questions raised in this little book seem paradoxical when first enunciated, but are all solvable on accepted scientific principles. They relate chiefly to Newton's law of gravitation. A neat mathematical solution is given to each of the problems, which are as follows:

1. Why is it that on March 21 and September 23 (the equinoxes) the sun at noon is not at its highest point, and also the day is longer than the night?

2. Why is the path of the moon about the sun, notwithstanding its monthly revolution about the earth, always concave to the sun?

3. Why have we winter when the sun is nearest the earth and summer when it is farthest away?

4. Why is the acceleration of gravitation zero at the centre of the earth and a maximum about one-seventh of the radius below the surface?

5. Why is the highest point of the tide produced by the moon not on the line joining earth to moon?

6. Why must a body at the earth's surface, when given a horizontal blow, deviate sideways?

7. Why is it that, in the case of a body thrown out from the earth's surface, the direction of the impulse has no influence in determining whether the path will be an ellipse, a parabola, or a hyperbola?

8. Why will the mean velocity of a body which revolves about another become more rapid if the system is transferred from a vacuum to a resisting medium—a nebula, for example?

9. To determine the path of a ray of light from a fixed star when under the attraction of the sun.

10. Why is the path of the moon (considered due only to the earth's gravitation) not lengthened through the sun's attraction in the direction earth-sun, but is more strongly curved or flattened?

C. A. C.

Le Mystérieux Univers, par Sir James Jeans, traduit par M. Billaudel et J. Rossignol. Paris: Hermann, 1931. Price 20 frs.

This is the French edition of Jeans's "The Mysterious Universe," which has achieved a remarkable success. Some months ago over 100,000 copies had been sold. This edition includes a pleasing portrait of the author. One can pardon the translators for a desire to claim some of Jeans's work for the French nation when they say: "Just as our first works on cosmogony are entirely due to a great French scientist, the Marquis de Laplace, so the subjects treated in the present little work owe much to the profound thought of two French scientists, the lamented Henri Poincaré and Prince Louis de Broglie, who by the fruitfulness of their ideas and the

richness of their labours have aroused the admiration of the physicists of the entire world."

The book is well printed and the price is reasonable. It will undoubtedly have a wide circulation among those who prefer the French language. C. A. C.

Mathematical Tables. Volume I. Prepared by The Committee of the British Association for the Calculation of Mathematical Tables. xxxvi, 72 pages. $8\frac{1}{4}\times 11$ in. Neill and Co., Ltd., Edinburgh.

The present volume of mathematical tables is the result of labours started in 1873 when a committee of the British Association was appointed to form a complete catalogue as far as possible of existing mathematical tables and to reprint or calculate tables which are necessary for the progress of mathematical sciences. This committee with changing personnel has made valuable contributions in the reports of the British Association from that time. In order to collect all the tables included in these reports and to present them in book form it was necessary, to fill in gaps in the arguments and to make facilities for interpolation. This labour has been carried out.

In the introduction, consisting of thirty-six pages, each table is explained and also the way the table is to be used. There are sixteen tables as listed below. The figures in brackets following the title of the table give (i) the range and interval of the argument, and (ii) the number of decimal places.

I. Multiples of $\frac{1}{2}\pi$ [1 (1) 100; 15].
II. Circular Sines and Cosines [Radians, 0.0 (0.1) 50.0; 15].
III. Circular Sines and Cosines (Radians, 0.000 (.001) 1.600; 11].
IV. Hyperbolic Sines and Cosines of πx [0.0000 (.0001) 0.0100; 15].
V. Hyperbolic Sines and Cosines of πx [0.00 (0.01) 400; 15].
VI. Hyperbolic Sines and Cosines of x [0.0 (0.1) 10.0; 15].
VII. Exponential Integral [0.0 (0.1) 15.0; 11].
VIII. Sine and Cosine Integrals [0.0 (0.1) 5.0, 5.0 (0.1) 20.0 (0.2) 40.0; 11, 10].
IX. Factorial Function [0.00 (0.01) 1.00; 12].
X. Integral of the Logarithmic Factorial Function [0.0 (0.01) 1.00; 10].
XI. Digamma Function [0.00 (001) 1.00, 10.0 (0.1) 60.0; 12], Digamma Function [0.00 (0.01) 1.00, 10.0 (0.1) 60.0; 12].
XII. Trigamma Function [0.00 (0.01) 1.00, 10 (0.1) 60.0; 12].
XIII. Tetragamma Function [0.00 (0.01) 1.00, 10.0 (0.1) 60.0; 12].
XIV. Pentagamma Function [0.00 (0.01) 1.00, 10.0 (0.1) 60.0; 10, 12].
XV. *Hh* Functions [—7.0 (0.1)+6.6; 10].
XVI. $Hh_0(x)\ Hh_2(x)/\ Hh_1(x)^2$. R. K. Y.

NEWS AND COMMENTS

The Henry Draper Medal, one of the gold medals in the hands of the National Academy of Sciences, was presented at its meeting in November to Dr. Annie J. Cannon, of the Harvard College Observatory, for her outstanding contribution to the spectral classification of the stars. This medal was established by Mrs. Henry Draper in 1883. The work on which the present award was based was supported by the Henry Draper Memorial, a gift to Harvard by the widow of Dr. Henry Draper, who obtained in 1872 the first photograph showing lines in a stellar spectrum.

Dr. Albert Einstein is once more at the California Institute of Technology and the Mount Wilson Observatory, where he will spend two months. He went via the Panama Canal without landing at New York. Professor W. de Sitter, of Holland, is also at the Mount Wilson Observatory.

A prize of $2,500, given by the Research Corporation of New York, was presented by the Chancellor of the Smithsonian Institution to Professor A. E. Douglass, director of the Steward Observatory, Tucson, Arizona, for his noteworthy researches on the growth-rings of trees, which have given information regarding the past climate of the earth and have revealed a correspondence between weather and solar activity.

Professor H. H. Plaskett of Harvard University, formerly of the Dominion Astrophysical Observatory at Victoria, B.C., has accepted the position of Savilian Professor of Astronomy and Director of the University Observatory, Oxford University, England. This professorship was established in 1619 by Sir Henry Savile. The observatory was founded in 1873-74 and the first director was Charles Pritchard. He was followed in 1893 by H. H. Turner, who died suddenly while at Stockholm in 1930. The best wishes of his many Canadian friends will go with Professor Plaskett in his new position.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

AUDIBILITY OF THE AURORA.

In a letter to *Nature* H. U. Sverdrup, of Bergen, Norway, offers an explanation of the sounds reported to have been heard by some persons at the time of auroral displays. He states that when the air is calm and the temperature is below – 40°F. one sometimes hears a swishing or hissing sound when exhaling the breath, possibly caused by the water vapour of the breath condensing to ice-crystals which collide together as they fall to the ground. He remarks that this explanation was given by Roald Amundsen who, in his book "The North Pole," says, "What one hears is one's breath which freezes in the cold air." Sverdrup further says that the "swishing breath" is a phenomenon well known to arctic travellers and to natives, but it is seldom mentioned in scientific literature, though Hann quotes observations of it in Siberia and A. Wegener reports having observed it in Greenland at temperatures below – 44°F.

The present writer is pleased to give the above explanation. He has been collecting for many years information regarding the audibility of the aurora, and references to it may be found in past volumes of this JOURNAL. It is doubtful if the above can satisfactorily explain all the cases cited. One of the most interesting of the examples given is in a note by the late W. F. King in vol. 1, page 193, (1907).

THE PARAGOULD METEORITE.

The following account of this very large meteorite is taken from the "Service Bulletin" (November 14, 1931) of the University of Iowa, at which place is Professor C. C. Wylie, who is an enthusiastic student of meteors.

At about four o'clock on the morning of February 17, 1930, Dan Bartholemew, engineer on a Santa Fe passenger train, saw what he thought was an airplane falling in flames, redder flames than that of an ordinary fire. At his next stop, Topeka, Kansas, he wired back to Burlingame suggesting that they make a search.

In East St. Louis, Illinois, at the same hour, Leonard Morrison, night man at a garage, saw what he assumed to be an airplane going down in flames near the Park airport. He sent his service man over to investigate.

The preceding paragraphs give impressions of persons hundreds of miles from Paragould, Arkansas. Within 70 miles of Paragould, the detonations attracted more attention than the light, awakening persons from sleep and stampeding stock on farms. The following account is from Beach Grove, a village near Paragould. Two young men, Charlie Norman and Willie Allison, were going fishing, driving in a farm waggon, when the landscape lighted up,—it seemed to them brighter than day. Looking up they saw a ball of fire with a tail, coming from the northeast. It passed overhead, and went out at an altitude of about 20 degrees in the southwest. The team, accustomed to bright automobile lights, paid little attention to the display, and the boys drove on without change of pace for perhaps a hundred yards. Here, an explosion which jarred things like an earthquake startled the boys and caused the horses to plunge. The first blast seemed to come from about where the meteor had disappeared, and following this a roar, as though a train were passing, rolled back along the path of the meteor. It crashed back to overhead in "no time", and then on to the northeast, the rumbling being audible for perhaps half a minute. At this point, according to Charlie, Willie wanted to turn round and go back home. However, when they had quieted the team and talked things over, the young men decided to go on with their fishing trip.

It appears that the meteor came very nearly from the northeast, and disappeared over a point a few miles west of Paragould, in Green county, Arkansas. The altitude of disappearance was about five miles, but the meteor may have burst into three pieces at a height of nearly ten miles. Five miles is a very low altitude for a meteor to show as a ball of fire, but this was a meteor of great mass, and it is known that big meteors are seen at lower altitudes.

A few hours after the appearance of the meteor, Raymond E. Parkinson, a farmer living near Finch, was going to the field to get his horses when he noticed a hole, with clods of fresh earth scattered chiefly to the northeast. A meteorite weighing about 80 pounds was recovered from the hole, which was measured as 34 inches deep. This stone was in the possession of the Paragould High School for a time, and was then purchased by Stuart H. Perry of Adrian, Michigan.

On Sunday, March 16, at about 8.30 a.m., W. H. Hodges, a farmer living a few miles southwest of Finch, discovered a big hole near his home, on land belonging to his neighbour, Joe H. Fletcher. These men, and Pete Smothers, put in a hard day's work, and at about 9.00 o'clock Monday morning brought up the big meteorite. The hole measured 8 feet ¾ inch deep, the bottom deviating about a foot to the southwest. This shows the stone was falling with a slight deviation in the direction of the meteor's travel. Scattering clods of clay were thrown, chiefly to the south,

which was nearly in the direction of travel, but also the direction of the slope of the land. These clods were quite numerous at a distance of 30 feet, and some were thrown 50 yards or more.

A New Record in Meteorites

Soon after the stone was removed from the ground, it was weighed on good cotton scales, and the weight determined as 820 pounds. The Long Island, Kansas, stone weighed over 1,200 pounds, but it was broken on a ledge of rock falling, and the date of fall is not known. The Knyahinya, Hungary, stone, 647 pounds, previously held the record for stones recovered intact, and it was also the largest meteorite for which date of fall was known. Late catalogues of meteorites list a 20-ton iron as falling near Bezerros, Brazil, on May 9, 1915. A recent investigation by C. C. Wylie, of the University of Iowa, has shown that this is based on nothing more substantial than a vague newspaper story. The account appears to refer to a bright meteor seen in northern Brazil some time in 1914, and apparently no meteorites were recovered. The Knyahinya stone has therefore been the largest meteorite for which the date of fall is known, and the largest stone meteorite not broken at the time of fall. Readers are reminded that several prehistoric irons weighing tons are accepted as authentic meteorites, but the date and circumstances of fall are not known for any of these. On the week end following his return from Arkansas, Professor Wylie called at the Field Museum in Chicago, as it was important that this new record in meteorites be placed in one of the best museums in America. Within a few weeks, the Field Museum succeeded in purchasing the big meteorite, and it is now on exhibition in that institution as "The Largest Meteorite Ever Seen to Fall." Its weight on reaching that institution was determined as 745 pounds. An unknown amount of material was knocked off between the time of finding and the time of reaching the museum, but there is no reason for doubting that 820 pounds represents approximately the original weight.

The Leonid Meteors in 1931.

At the time of this shower the skies over Toronto and vicinity were almost continuously covered with clouds, and as a consequence very few meteors were observed. But at some other places conditions were satisfactory and *Science News Letter* reports that the display was the best in years.

Professor C. P. Olivier observed the meteors from the estate of John A. Kingsbury, an amateur astronomer, in Ulster county, N.Y. The site was high up on the Catskill mountains; there the

sky was clear, though fog covered the lower ground. The display was best on Tuesday morning, November 17, and with the assistance of ten other observers a total of 2500 meteors was reported. Professor Olivier himself observed 266 meteors, 90 of which came between 3.30 and 4.00 a.m. There were several fine fireballs, including two whose trains lasted twelve minutes each.

In Arizona on the same morning A. W. Beck, of the Steward Observatory, with a party of observers saw many meteors whose "brightness was conspicuous, mostly brighter than Jupiter and few fainter than Sirius." One left a trail which persisted for ten minutes, one for seven and several for five. During the three hours of observation the meteors fell at an average of seventy per hour.

During this shower measurements of the height of the Heaviside layer were made by A. M. Skellett at the Bell Telephone Laboratories at Deal, N.J. and he reports that on November 16 there was a very erratic and disturbed condition of the layer—very different from that occuring during a magnetic storm. He attributes it to a cloud of electrified particles which accompanies every meteor in its descent.

THE NATIONALITY OF COPERNICUS.

Two months ago I printed in this column a brief note, written by a Polish editor, regarding the nationality of Copernicus. This subject has been often debated, sometimes with more warmth than wisdom, and it would be unwise to re-open it. However, it may be of interest to refer to some recent discussions of the matter. In 1920 was published a sixty-page pamphlet by G. Bender, entitled "Heimat und Volkstum der Familie Koppernigk," which was reviewed in the quarterly publication of the Astronomische Gesellschaft for 1923. In it the author deals with the family of Copernicus rather than with the man himself. Reasons are given for considering it to be German.

I also examined F. Boquet's interesting "Histoire de l'Astronomie" (Paris, 1925). The author quotes the following sentence from the sprightly Fontenelle's "Plurality of Worlds" (here given is in an English translation): "Imagine then a German called Copernicus, confounding everything, tearing in pieces the beloved

circles of antiquity." This unfortunate phrase, he declares, was the signal for German writers to claim Copernicus as a German. This was a new idea to me. I presume the question will never be answered satisfactorily to all parties and we must consider Copernicus as belonging to all nations.

Before finally dismissing the subject I may refer to a case in quite recent times where the question of one's birthplace was of importance. As is well known, Canadians are allowed special privileges in entering the United States. Not very long ago an able graduate of one of our universities wished to proceed to a large American institution to continue his work, but when he informed the immigration official that he was born of Canadian parents while they were stationed in China as missionaries he was refused admission.

PROFESSOR DE SITTER'S LECTURES.

Professor W. de Sitter, of Leyden, Holland, who has been in America since the middle of October, gave four lectures in Toronto, November 18 to 21. Two were on "Measuring the Size of the Universe," one on "The Rotation of the Earth," and the fourth on "The Size of the Universe." For the first two lectures there was an audience of about 250, upwards of one half being students and members of the staff of the University. The third lecture was before the Mathematical and Physical Society, an undergraduate organization which has been in existence fifty years. The fourth address was one of the series of popular lectures offered by the Royal Canadian Institute, and about 1200 persons attended it. Representatives from Ottawa, Kingston and London were present. Mrs. de Sitter accompanies her husband, and they expect to sail for home at the end of January from San Francisco, going by way of the Panama Canal.

C. A. C.

VANCOUVER CENTRE OF THE R.A.S.C.

By L. GILCHRIST, *General Secretary*

A centre of the Royal Astronomical Society of Canada is in process of formation at Vancouver, British Columbia. At the recent meeting of the Council of the Society the President was empowered to approve of the formation of the Centre at Vancouver as soon as all of the formalities associated with the formation of a Centre are completed.

The following is the list of prospective New Members that has been received from Mr. H. C. B. Forsyth, Davis Chambers, 615 Hastings Street West, Vancouver, B.C.

W. F. Heller, R.R. No. 1, Milner, B.C.
J. L. Bennett, 3414-23rd Ave. W., Vancouver
Richard C. Simpson, R.R. No. 1, Milner, B.C.
Norman H. Hawkins, 4716-4th Ave. W., Vancouver
William T. Farrell, 5850 Highway St., Vancouver
C. F. Parker, 2331-45th Ave. W., Vancouver
O. W. Pullan, 4423-9th Ave. W., Vancouver
W. Stothard, 1480 King Edward E., Vancouver
Mrs. C. M. Robson, 4716 University St., Vancouver
C. A. McDonald, 3042 York Ave., West Burnaby
John Stater, 1941 Sussex Ave., West Burnaby
H. A. Pitman, Port Coquitlan, B.C.
L. N. Earle, 6059 Elm St., Vancouver
S. A. Richmond, 2929-13th Ave. W., Vancouver
M. M. McGrath, 546 Kaslo St., Vancouver
H. Grayson Smith, Dept. Physics, University B.C., Vancouver
Miss Kathleen Ward, 3519-14th Ave. W., Vancouver
Miss Marjorie Speed, 4446-11th Ave. W., Vancouver
D. G. Cameron, 2090 Pendrell St., Vancouver
E. L. Cassady, 108 Queens Avenue, New Westminster
J. A. L. McAlpine, 2531 Point Grey Road, Vancouver
D. G. Cameron, 2090 Pendrell St., Vancouver

It is understood that several other names will be added to the list shortly. The suggestion is also made that members of the Victoria Centre who live on the mainland will if they wish be transferred to the Vancouver Centre.

It is apparent that the Centre at Vancouver is commencing its New Year under very happy conditions and with very bright prospects and it may be indicated also with the congratulations and best wishes of all members of the Royal Astronomical Society.

MEETINGS OF THE SOCIETY

At Vancouver

The newly organized Vancouver Centre of the Royal Astronomical Society of Canada held its first open meeting at the University of British Columbia on Tuesday, November 10th, with a good attendance of members, university students and general public.

Dr. Daniel Buchanan, Dean of the Faculty of Arts and Science and Professor of Mathematics at the University of British Columbia, the Honorary President of the Centre, gave the address, choosing as his subject "The Making of Worlds", or "Cosmogonies, Ancient and Modern." He gave a very interesting historical survey of the various theories which were held concerning the solar system and the universe from the time of Pythagoras to that of Newton. This was followed in the second half of the address with an illustrated discussion of the nebular, planetesimal and collision theories of the origin of the solar system, together with some of the objections to these views. The lecturer concluded with a short description of the modern views concerning the nature of spiral nebulae and the structure of the galaxy.

H. Grayson Smith, *Recorder.*

At Toronto

October 6—The opening meeting of the 1931-32 season was held in the Physics Building of the University of Toronto, Mr. J. R. Collins taking the chair in the absence of Mr. R. A. Gray.

Several of the members reported on observations made during the summer.

Professor Chant lectured on "Pluto, the ninth planet", and commenced with a description of Herschel's discovery of Uranus, the first expansion of our solar system. A short history was given of Herschel's accomplishments in the art of speculum making, and tribute paid to his ability and tenacity of purpose in overcoming seemingly insuperable obstacles. The lecturer reviewed the remarkable discovery of Neptune by Adams and Leverrier, assuredly one of man's finest intellectual conquests. The perturbations of Uranus and Neptune still unexplained forced astronomers to suspect the existence of another body farther out in space. Prof. Lowell's remarkable computations of the position and orbit of this body, later discovered by his successors at Flagstaff Observatory and named Pluto, probably deserve as great fame as those of the discoverers of Neptune. The lecturer also referred to the excellent work on trans-Neptunian planets by Prof. W. H. Pickering.

October 20—A regular meeting, for members only, was held at 8 p.m., Mr. R. A. Gray in the chair.

There were six elections to membership—

F. Jno. Bell, Royal Bank Building, Toronto.
Robert P. Hall, 313½ Yonge St., Toronto.
M. A. Landenburger, Philadelphia, Penna.
L. J. Gosier, 126 5th Avenue, Oswego, N.Y.
G. H. Olewin, 1619 Marmora Avenue, Chicago, Ill.
J. J. Hayes, Salt Lake City, Utah.

Several members reported on observations of meteors and an auroral display. Mr. A. R. Hassard described, in his usual interesting manner, his observations of Saturn, and referred to the present low level of Lake Ontario.

Mr. J. R. Collins spoke on "Some little known Cosmic theories of Newton". In his hypothesis of the nature of light and heat, Newton admitted the existence of a fluid, imperceptible to our senses, which extends everywhere in space, penetrating all bodies, with different degrees of density. This fluid, which he termed "Aether", to characterize its extreme tenuity, he considered as highly elastic, pressing against itself and material bodies with a power according to its density, causing these bodies to bend towards one another, the inequality of the pressure urging them from the denser into the rarer parts of the aether.

Newton supposed light to consist of a peculiar substance different from the aether, and composed of heterogeneous particles, which, springing in all directions from shining bodies, agitate the aether in their passage, and in it excite undulations, by meeting of which they, in their turn, become liable to be accelerated or retarded. Newton endeavoured to explain that the inflections undergone by rays of light when passing the extremities of bodies, are due to variations in density of the aether near the surface of the body.

Many of the members present took part in the interesting discussion which followed.

November 3, 1931.—A regular meeting was held in the Physics Building of the University at 8 p.m. Mr. R. A. Gray in the chair.

There were four elections to membership:—
John Whitehouse, 17 Boswell Avenue, Toronto.
G. H. Mallory, B.A., 399 Roehampton Avenue, Toronto.
Roy T. Merkel, B.S., Sinking Spring, Pa. U.S.A.
Charles F. Johnson, Jr., Kis-Lyn, Pa., U.S.A.

Mr. R. A. Gray then gave the paper of the evening on "How the distances of the stars are determined by Cepheid Variables." The speaker explained two methods of finding the distances of stars. The well-known trigonometrical method required the longest possible base line that can be found which is the diameter of the earth's orbit round the sun. At intervals of six months observations are made of the angle at the vertex of the triangle having the star in question as vertex, and its base the diameter of the earth's orbit—a distance of 186,000,000 miles. With the increasing perfection of telescopes and the use of photographs the angle can be found very accurately indeed,

and consequently the distance of the star. The distances of nearly 2,000 stars are known by this method.

To calculate the distances of more remote stars, other methods must be used, a very powerful method being that of the Cepheid variables. These stars, of which a large number are found in the Magellanic Clouds and in star clusters, are named after delta Cephei, in the constellation Cepheus, which was the first star of this type to be studied. These stars alternately fade and brighten at regular intervals of from a few hours to several days; as a rule they brighten more rapidly than they fade, which is the chief characteristic of Cepheids. At Harvard Observatory it was discovered that there is a close relation, called the period-luminosity law, between the period of variation and the absolute magnitude of the star. The absolute magnitude can also be determined from the class of spectrum that the star gives. Now knowing the apparent magnitude of the star and its absolute magnitude the parallax of the star can be calculated and consequently its distance. Distances of stars calculated by this method correspond very closely with those found by using the trigonometrical method, in cases where the stars are near enough for both methods to be applied, confirming the truth of the period-luminosity law. The distances of short period variables can now be ascertained and at the same time the distances of star clusters in which Cepheid Variables appear.

December 1, 1931.—A regular meeting was held in the usual place at 8 p.m. Mr. R. A. Gray in the chair.

There was one election to membership:—

Mr. T. Pilkington, 13 Bowden Street, Toronto 6.

Mr. Wm. Gore, C.E., was the speaker for the evening, and gave as his subject, "Toronto's great Engineering Feat, the new Waterworks Tunnel." Mr. Gore, in his capacity of consulting engineer in this huge undertaking, is well qualified to deal with this subject.

The new Toronto waterworks system, now in course of construction, provides for much larger quantities of water, a wider area of distribution, and for more extended future requirements. The existing works are to be maintained as heretofore, and when combined with those to be constructed immediately, will ensure a pure and palatable water supply, sufficient for the needs of over 1,000,000 persons and eventually for a population of 1,500,000. The extensions are being designed so that construction work will be carried out in two stages, providing in each case for an additional average daily supply of 75,000,000 gallons, but wherever it appears more economical to do so, provision is allowed in the first construction for the complete scheme.

One of the reservoirs will contain 50,000,000 gallons in two separate compartments and is constructed of reinforced concrete. The tunnel

portal has been featured architecturally and provides access to the reservoir and grounds.

The lecturer explained the method used in locating the position of each traverse, for the boring of the tunnel, which extends along the waterfront, the full width of the city. Several shafts were sunk along the route to the depth of the proposed tunnel. To determine the direction for boring between the shafts plumb lines were extended down the sides of each shaft, then by sighting a telescope in the direction of the next shaft, both wires could be brought into exact alignment. This procedure was followed at the bottom of the shaft, the alignment of the two wires giving the direction for the boring of the tunnel. Slides depicted the various operations of boring and lining the tunnel with concrete, also showing the types of buildings and reservoirs. The lecture evoked some very interesting discussion and tribute from an appreciative audience.

S. C. BROWN, *Recorder.*

AT LONDON

October 9—A regular meeting of the London Centre was held at 8 p.m. in the London Life Building. There were 66 people present, with one election to membership in the Society, viz., Mr. C. H. Gould, 470 English St., London, Ont.

A brief description of the Engineer's Transit was presented by Professor G. H. Reavely of the Department of Geology, University of Western Ontario. By means of diagrams, Professor Reavely explained how the direction of true north may be obtained by observing the direction of Polaris at greatest elongation.

President McKone next introduced Mr. F. H. Coates of the Department of Biochemistry, Medical School, University of Western Ontario, who delivered an illustrated lecture on "Astronomical Facts of the Great Pyramid". The most remarkable of the Egyptian pyramids are those belonging to the group at Gizeh, four miles south-west of Cairo. The largest of this group, known as the Great Pyramid, is the pyramid of Cheops (King Khufu). The first part of the lecture was devoted to a description of the size and construction of this pyramid, the immensity of the structure being vividly portrayed by means of lantern slides.

The Great Pyramid has a natural limestone rock foundation, the base of the pyramid forming a square which covers a space of 13 acres. The pyramid is built chiefly of the hard limestone of the district but large granite blocks were also used on the outside. The outer surface of the four walls forms a series of steps, each slightly over three feet in height. The four sides are slightly concave towards the interior, the speaker illustrating this hollowing-in feature by taking a cardboard pyramid and pinching in the four sides at the vertex of the model. The cardboard model which the speaker used had been built in sections, and when these sections were separated there was dis-

played a cross section of the interior of the Great Pyramid. The entrance into the interior is located in the north face of the pyramid, at the 35th course of steps. The descending passage from this entrance branches, lower down into two tunnels, one, known as the Grand Gallery, is inclined upward at an angle of about 40° from the horizontal and leads into the King's Chamber, a room about 34 feet long, 17 feet wide, and 19 feet high. The second tunnel is inclined downward at an angle of 30° from the horizontal and proceeds to the subterranean Well, located in the base of the pyramid. The original tunnel into the King's Chamber is sealed by a huge block of granite. About 600 A.D. an Arab, Al Mahmoun, in search of plunder, constructed a new tunnel which passed completely over the obstruction in the Grand Gallery, and this entry into the inner Chamber of the King is in use to-day.

The speaker expressed the view that the Great Pyramid was planned primarily to reflect the sun's light and secondarily to cast shadows. It was a sun dial not only of the day but also of the seasons, giving accurately the days of winter solstice, spring equinox, summer solstice, and autumnal equinox. The purpose of the hollowing-in feature of the sides of the pyramid was to prevent the diffusion of the reflected light and to stabilize the reflected rays under the influence of variable surface refractions. The beam of light reflected from the south face of the pyramid is truly horizontal on only two days of the year; these two days are midway between the vernal equinox and summer solstice and midway between summer solstice and autumnal equinox. Between these two days the noon reflections from the south face form triangular images on the ground and at no other period of the year is this true. The length of these reflected triangles approaches a minimum at summer solstice, after which the images lengthen again until noon of the last day of summer, when the moon reflection becomes horizontal again.

The lecture was concluded with the remark that in the year 2014 B.C. an observer in the subterranean Well on looking back along the tunnel which leads up to the north face could see the Pole Star of that date framed in the tunnel entrance.

Mr. McKone thanked Mr. Coates for his instructive address. Mr. T. C. Benson discussed by means of charts the constellations Lyra, Cygnus, and Aquila. The meeting then adjourned in order to allow the members to proceed to the roof of the building for outside observations, under the direction of Mr. Benson.

November 15, 1931.—A regular meeting was held at 8 p.m. in the London Life Building. There were 48 people present, with two elections to membership in the Society, viz.,

Mr. Lawrence Owen, Box 31, Ingersoll, Ontario.

Mr. A. J. Doke, 245 Briscoe St., London, Ontario.

President McKone introduced the speaker of the evening, Prof. G. H. Reavely, of the Department of Geology, University of Western Ontario, who delivered a lecture on "The Ice Age". The lecture was illustrated through-

out, and some very interesting local slides were shown. The speaker first described the formation of glaciers. The following facts were given as geological evidence of the presence of glaciers over the continent of North America: (1) Two soil layers; (2) Foreign material in various localities; (3) Boulders and pebbles were scratched throughout the provinces; (4) "Chatter" marks, indicating the direction of movement of the glaciers; (5) Old stream beds were filled up by material which was dumped into them by glaciers; (6) Low ranges of rounded hills—chiefly dumps of gravel, deposited by glaciers.

The extent of glaciation in North America was discussed, the speaker pointing out that in Canada there were two main regions, known as the Labrador Ice Sheet and the Keewatin Continental Ice Sheet—the former being responsible for the formation of Niagara Falls and the Great Lakes. The glacial history of the Great Lakes was described in detail.

The speaker was of the opinion that there had been at least three ice ages in the history of North America—the last period of glaciation, which extended across Ontario to the central Ohio valley, took approximately 10,000 years to recede northward to the northern shores of Lake Ontario and approximately 30,000 years to recede from north of Lake Ontario to Hudson Bay. The lecture was concluded with a short discussion of the evidences of man in glacial periods. In North America there is evidence that man existed at least 200,000 years ago.

A vote of thanks to Professor Reavely was proposed by Rev. R. J. Bowen and adopted by the Society. Mr. F. H. Coates gave a short demonstration of the Optical Range Finder. The meeting then adjourned for outside observation from the roof of the building, under the direction of Mr. T. C. Benson.

November 30, 1931.—A dinner in honour of Dr. S. A. Mitchell, Director of the Leander McCormick Observatory, University of Virginia, was held at 6 p.m. in Wong's Cafe, London. There were 52 members of the London Centre present, with 6 guests, including President W. Sherwood Fox of the University of Western Ontario and Mr. E. C. Mitchell, brother of Dr. Mitchell. At the conclusion of the dinner Dr. Mitchell replied informally to the welcome which President McKone of the London Centre had extended.

The dinner party then adjourned to the Auditorium of the London Life Building, where Dr. Mitchell delivered an illustrated lecture, "To the South Seas with an Astronomer." The lecture was sponsored jointly by the Extension Department of the University of Western Ontario and the London Centre of the Royal Astronomical Society. There were 360 people present. Dr. Fox acted as chairman and the speaker was introduced by Dr. H. R. Kingston. Dr. Mitchell told of his travels over the world to view eclipses of the sun—in particular, of his visit to "Tin Can" Island in the South Seas for the eclipse of 1930. At the conclusion of the lecture a vote of thanks was proposed by President McKone of the London Centre, seconded by Dr.

W. F. Tamblyn of the University of Western Ontario, and enthusiastically approved by the audience.

Officers for 1932:—

Honorary President—Dr. H. R. Kingston, F.R.A.S.
President—E. H. McKone, B.Paed.
Vice-President—T. C. Benson.
Secretary-Treasurer—G. R. Magee, S.M.
Councillors—F. H. Coates, A. Callard, F. W. Daly, F. Fisher, G. A. Minhinnick.

G. R. MAGEE, *Secretary-Treasurer.*

AT VICTORIA

November 24, 1931.—The annual meeting of the Centre. In the chair, N. C. Stewart, Esq., vice-president.

The Librarian, Secretary and Treasurer presented reports for 1931.

On the motion of Mr. H. Boyd Brydon it was agreed to express appreciation to the editors of local newspapers for the publication of reports of meetings.

Dr. C. S. Beals delivered a lecture on "Distant Universes." Several lantern slides showed nebulae, spiral and irregular, and the lecturer spoke of their size and distance, velocity and direction. Dr. Beals concluded with a brief reference to Einstein's theory of relativity.

Messrs. W. E. Harper and J. Petrie, having been appointed scrutineers for the election of officers for 1932, reported as follows:

Honorary President—Dr. J. A. Pearce.
President—Philip H. Hughes.
First Vice-President—N. C. Stewart.
Second Vice-President—Capt. J. N. Hughes.
Librarian—W. T. Bridge.
Secretary-Treasurer—H. Boyd Brydon, 2390 Oak Bay Avenue, Victoria.
Councillors—John Dean, Rev. J. Goodfellow, Charles Hartley, J. P. Hibben, Dr. Frank Hogg.

The following Past Presidents are ex-officio members of the Council:—Dr. J. S. Plaskett, F.R.S., F. N. Denison, W. S. Drewry, W. E. Harper, M.A., James Duff, M.A., P. H. Elliott, M.Sc., Dr. C. S. Beals.

P. H. HUGHES, *Secretary.*

The Royal Astronomical Society of Canada

OFFICERS FOR 1931

Honorary President—R. M. STEWART, M.A., F.R.S.C., Ottawa.
President—H. R. KINGSTON, M.A., Ph.D., London, Ont.
First Vice-President—R. K. YOUNG, Ph.D., Toronto.
Second Vice-President—MGR. C. P. CHOQUETTE, M.A., Lic.Scs., Montreal.
General Secretary—LACHLAN GILCHRIST, M.A., Ph.D., 198 College St., Toronto.
General Treasurer—J. H. HORNING, B.A., 198 College St., Toronto.
Recorder—E. J. A. KENNEDY, Toronto.
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